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# Versatile Inelastic Neutron Spectrometer (VINS) Project for J-PARC

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## Abstract

We have proposed a Versatile Inelastic Neutron Spectrometer (VINS) for the spallation neutron source at the Materials and Life Science Facility (MLF), Japan Proton Accelerator Research Complex (J-PARC). VINS is a direct-geometry Fermi chopper spectrometer designed to provide considerably high neutron flux with moderate energy and  $Q$  resolutions. VINS is characterized by its wide energy and  $Q$  range ( $0.5 < \Delta E < 1000$  meV and  $Q < 40 \text{ \AA}^{-1}$  at  $\Delta E = 1000$  meV), enabled by an array of detectors covering large solid angle [ $-30 < 2\theta < 130$  degrees horizontally and  $-30 < \phi < 30$  degrees vertically (2.8 Sr)]. Monte-Carlo ray-tracing simulation estimates the sample position neutron flux as high as roughly  $1 \times 10^6$  neutrons/cm<sup>2</sup>/sec for the  $\Delta E/E_i \sim 5\%$  mode at  $E_i = 10$  meV. With these wide  $E$ - $Q$  coverage and high neutron flux, VINS will be one of the most efficient and versatile inelastic spectrometers at J-PARC. Target science ranges from conventional solid-state physics, such as highly correlated electron systems, frustrated magnets and relaxors, to rather interdisciplinary areas, exemplified by glasses, quasicrystals, polymers and liquids. A particular focus is placed on extreme sample environments; high-magnetic-field and high-pressure environments are planned. © 2001 Elsevier Science. All rights reserved

**Keywords:** Spallation neutron; Direct geometry spectrometer; Fermi chopper; Inelastic neutron scattering; Condensed matter physics; Chemistry;

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## 1. Introduction

Neutron inelastic scattering is a powerful tool for condensed matter research; it can provide dynamical structure factor in the energy ( $E$ ) and momentum-transfer ( $Q$ ) space, which cannot be obtained by other means. However, due to small scattering cross-sections between nuclei/spins and neutrons, it always requires a considerably large amount of sample. This limits neutron inelastic scattering technique to the scientific issues that can provide sufficiently large samples. A revolutionary intense neutron source, Japan Proton Accelerator Research Complex (J-PARC), has been under construction. This MW-class spallation neutron source will definitely open a new era for the inelastic neutron scattering research, removing the sample size limitation from the neutron inelastic scattering.

A standard realization of inelastic neutron scattering spectrometer at pulsed neutron sources may be a direct-geometry Fermi chopper spectrometer. At J-PARC, two Fermi chopper spectrometers have been under construction. First one, a High Resolution Chopper spectrometer (HRC), is aimed at investigating excitations in a wide energy range up to 2 eV with very high energy resolution of  $\Delta E/E_i < 1\%$  [1]. Second one, 4SEASONS, is rather science-oriented spectrometer, targeted to the high- $T_c$  research, with very high intensity and moderate  $Q$  and  $E$  resolutions [2]. Here, we describe another inelastic spectrometer proposal to J-PARC: the Versatile Inelastic Neutron Spectrometer (VINS). This spectrometer is aimed at maximizing versatility and efficiency in inelastic neutron scattering research, by virtue of high neutron flux at the sample position and wide-solid-angle coverage of detector array. First priority for the spectrometer design has been given in its versatility, in order to be useful for various types of condensed matter research ranging from solid state physics to soft matters. From this viewpoint, large coverage of energy and  $Q$  range is essential. On the other hand,  $E$  and  $Q$  resolutions may be rather moderate to obtain the high neutron flux; standard mode provides  $\Delta E/E_i < 5\%$ , whereas an option for the high-energy-resolution mode  $\Delta E/E_i < 2.5\%$  will be equipped. Flexibility for sample environments is

also another issue; developments of high pulse magnetic field, high pressure and ultra-low temperature apparatuses are planned in this VINS project. The details of the conceptual design of VINS will be given elsewhere [3].

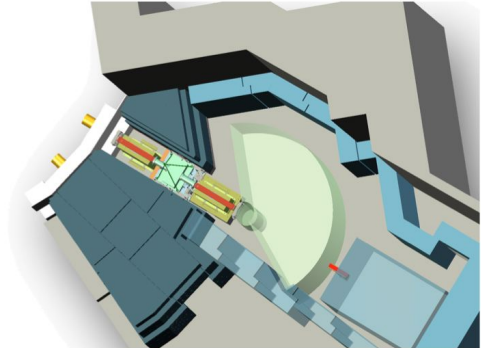


Fig.1 Schematic drawing of the Versatile Inelastic Neutron Spectrometer situated at BL23 of J-PARC/MLF.

## 2. Spectrometer Details

Overview of the proposed spectrometer VINS is schematically drawn in Fig. 1, whereas summary of spectrometer parameters is given in Table I. Details of the parameter determinations are described below.

To achieve high brilliance with moderate energy resolution, this spectrometer is planned to use the decoupled-liquid-hydrogen moderator. A short incident flight path is essential for high sample-position flux in higher-energy regions ( $E_i > 100$  meV), where neutron supermirror loses its effect. Therefore, the incident flight-path length was determined to be  $L_1 = 11.8$  m, which is the minimum at J-PARC/MLF. In addition, to obtain higher flux in the low-energy region, we plan to install 3Qc supermirrors in the incident flight path from  $L = 2.3$  m to  $L = 10.8$  m. We have estimated that the insertion of the supermirror will result in more than four times higher flux in the low energy region ( $E_i < 20$  meV).

The heart of this spectrometer is, of course, the Fermi chopper. VINS will have three different Fermi

choppers, providing three different operational modes. The Fermi chopper parameters are summarized in Table II.

Table I: Summary of spectrometer parameters of VINS.

Components	Parameter descriptions
Moderator	Decoupled H <sub>2</sub>
Length	
Moderator to sample (L <sub>1</sub> ) (m)	11.8
Sample to detector (L <sub>2</sub> ) (m)	2.5
Fermi chopper to sample (L <sub>3</sub> ) (m)	1.0
Incident guide tube	3Q <sub>c</sub> supermirror
Scattering Angle	-30 < 2θ < 130 deg. (horizontal) -30 < φ < 30 deg. (vertical)
Energy resolutions	
Standard	ΔE/E <sub>i</sub> ~5%
High-resolution	ΔE/E <sub>i</sub> ~2.5%
Relaxed	ΔE/E <sub>i</sub> ~5%
Energy range	
Standard	1 < E <sub>i</sub> < 1000meV
High-resolution	1 < E <sub>i</sub> < 500meV
Relaxed	1 < E <sub>i</sub> < 100meV
Sample Size	20X20mm <sup>2</sup>
Detectors	1 inch <sup>3</sup> He PSD

For a Fermi-chopper spectrometer, so-called optimum condition may be achieved when the chopper opening time  $\Delta t_{\text{ch}}$  becomes equal to the moderator pulse width  $\Delta t_{\text{mod}}$ . For the standard chopper mode, the chopper parameters were chosen so as to achieve the optimum condition at  $E_i = 400$  meV with the rotation frequency being  $f_{\text{ch}} \sim 400$  Hz. This ensures that the same Fermi chopper can be used at the highest incident energy 1 eV with the technically achievable rotation frequency  $f_{\text{ch}} \sim 630$  Hz. On the other hand, the high-resolution chopper will provide the higher energy resolution,  $\Delta E/E_i \sim 2.5\%$ , which may be required in some special occasion. This chopper may be operated up to  $E_i = 500$  meV, restricted by the maximum rotation frequency. For the above two choppers, the slit gaps are quite narrow (such as 1.2 mm for the standard Fermi chopper), so that the choppers indeed have a

collimation effect for the incident neutrons. This collimation effect may become a flux-reduction factor at low  $E_i$  where the divergence of the incident neutrons is considerable due to the supermirror guide tube. Hence, a new chopper with relaxed collimation is designed; with the wider gap of 5 mm, an optimum condition is realized at  $E_i = 100$  meV and  $f_{\text{ch}} = 600$  Hz. This relaxed chopper will accept up to 4° divergent beam, which is comparable to the supermirror divergence at  $E_i \sim 2$  meV.

It may be noteworthy that VINS will provide relatively large spatial freedom around the sample; empty space of at least  $R = 0.3$  m is expected at the present moment. This is to introduce various kinds of sample environments such as the high-pressure cell and pulse magnet. The sample size is assumed to be 20x20 mm<sup>2</sup>.

A secondary spectrometer comprises the secondary flight path (L<sub>2</sub>) and array of one-dimensional <sup>3</sup>He position-sensitive detectors, and is used for energy analysis of the scattered neutrons. Secondary flight path L<sub>2</sub> is chosen as  $L_2 = 2.5$  m so that the primary and secondary spectrometers have comparable energy resolutions. We also plan to have a large solid-angle coverage for the detector array; presently, coverage of  $-30 < 2\theta < 130$  deg. (horizontal) and  $-30 < \phi < 30$  deg. (vertical) is planned. Resulting solid angle is 2.8 Sr. The detector tube radius is 1 inch, which gives reasonable matching of outgoing beam divergence to the incident side for most of the energy range.

Table II: Summary of Fermi chopper parameters of VINS.

	Standard	High resolution	Relaxed
Curvature (m)	1.74	1.23	0.58
Slit gap width (m)	0.0012	0.0006	0.005
Diameter (m)	0.125	0.125	0.125
Max. incident energy (meV)	1000	500	100

The sample position flux was estimated for the three operational modes using the McStas Monte Carlo simulation code [4]. The results are shown in Fig. 2. For the standard mode, the sample position flux is almost flat in high energy range, with increasing behavior at lower energies, reaching  $8 \times 10^5$

neutrons/cm<sup>2</sup>/sec at  $E_i \sim 10$  meV. We note that quite high flux of  $5 \times 10^4$  neutrons/cm<sup>2</sup>/sec is expected even at 1 eV, which makes VINS a powerful tool for the entire energy region. On the other hand, for the high intensity mode the relaxed neutron divergence at the sample position provides further increase in the low energy range;  $10^6$  neutrons/cm<sup>2</sup>/sec may be obtained at  $E_i \sim 10$  meV. The high-resolution mode provides considerably lower flux, and thus may be used only in special cases where the high-energy resolution is crucial. It have to be noted that the present Monte-Carlo simulation has been performed assuming ideal devices; in particular, a finite slit blade thickness of the Fermi chopper was not taken into account, and thus a factor-of-two reduction of the sample-position flux may easily be seen in reality.

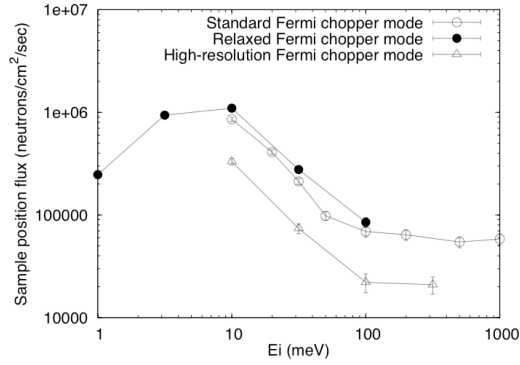


Fig.2: Monte Carlo estimation of the sample position flux. McStas ray-tracing package was used [4]. As the source component, the decoupled-liquid-hydrogen moderator running at 1 MW was assumed in the simulation [5].

funnel in front of the sample and incident guide tube. Such optimization is now in progress.

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## 3. Conclusions

Conceptual design of the Versatile Inelastic Neutron Spectrometer (VINS) has been described with estimations of its performance. High neutron flux, as well as large coverage of  $E$ - $Q$  space will make VINS a unique tool for a wide range of condensed matter researches. There is a further possibility to improve the performance of VINS by optimizing several components, such as converging